Faculty of Engineering

DESIGN OF MICROWAVE SENSOR USING WIDEBAND BAND PASS FILTER FOR MEASURING RICE QUALITY

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Bachelor of Engineering (Hons) in Electronics

(Telecommunications)

2017

UNIVERSITI MALAYSIA SARAWAK

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Final Year Project Report ☑

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DESIGN OF MICROWAVE SENSOR USING WIDEBAND BAND PASS FILTER FOR MEASURING RICE QUALITY

AMEERUL FIQRI BIN ABU BAKAR

This project is submitted in partial fulfilment of the

requirement for the degree of

Bachelor of Engineering (Hons) in Electronics

(Telecommunications)

Faculty of Engineering
Universiti Malaysia Sarawak

2017

I dedicate this thesis to my beloved family and my teddy bear

for their countless support, patience, and inspiration.

ACKNOWLEDGMENT

Alhamdulillah, all praises to Allah the Almighty for all His blessing, all of the outcomes are by His will. All of my actions would have not been possible without His blessing and guidance.

I would like to express my deepest appreciation to my Final Year Project supervisor, Dr Dyg Norkhairunnisa Abang Zaidel for her supports, expertise, time, and encouragement throughout the semester. Not forgetting my appreciation to Dr Kismet Hong Ping, Dr Shafrida Sahrani, and Dr Dyg Azra Awg Mat for their valuable assistance during the whole period of my studies. Also to my fellow comrades who are willing to share their thoughts and knowledge throughout the semester.

Finally, I would like to acknowledge my lovely family for their countless supports in many aspects which eased the flow of my learning process, and my most valuable ally Dayang Norfaranina Datu Unoi for her willingness to provide any possible and necessary assistance.

ABSTRACT

The application of microwave sensor has played many parts in industries such as aviation, telecommunication, medical, food, and many more. Microwave sensor is a device that detects short wavelength to extract information without having to touch the materials detected. In industry such as rice industry had utilized the application of microwave sensor to classify the rice quality and categorized it according to its price. The devices that are widely used such as '*Sinar AP model 6060'* or Scanning Electron Microscope is effective at detecting quality of rice. However, the prices of these devices are substantial.

This thesis investigates on the wideband band pass filter design operation and design wideband band pass filter as a low cost microwave sensor for characterizing quality of rice. The technique employed in designing the filters is broadside-coupled microstrip-slot technique. The filter is design and simulate by using electromagnetic simulation tools. There are three filters to be designed and the results are compared. The insertion loss and return loss is analysed. Insertion loss means that the loss of signal during transmission in a device whereas return loss means the loss of power due to its being reflected to its source Therefore, a good characteristic for a filter is that with high return loss and low insertion loss. As all the filter were optimized and the results were determined, the filters were fabricated. This thesis concludes that Type 2 performs the best compared to Type 1 and Type 3. The results obtained shows Type 2 has the highest return loss which is 25.32 dB and lowest insertion loss which is 0.15dB.

ABSTRAK

Pengunaan pengesan gelombang mikro memainkan peranan penting dalam industri seperti industri penerbangan, telekomunikasi, perubatan, makanan, dan sebagainya. Pengesan gelombang mikro merupakan alat untuk mengesan gelombang rendah bagi mendapatkan maklumat berkaitan dengan bahan yang diuji tanpa menyentuhnya. Dalam industri makanan seperti beras, penggunaan pengesan gelombang mikro diguna untuk menentukan kualiti beras dan harga ditentukan berdasarkan kualiti. Peralatan seperti '*Sinar AP model 6060'* dan mikroskop imbasan elektron juga digunakan secara meluas dalam industri. Walau bagaimanapun, instrumen seumpama ini sangat mahal harganya.

Tesis ini mengkaji operasi penapis laluan jalur lebar dan mereka penapis laluan jalur lebar sebagai alat kos rendah yang boleh menggantikan peralatan seperti '*Sinar AP model 6060'* dan mikroskop imbasan elektron. Teknik yang digunakan untuk mereka penapis laluan jalur ini adalah teknik '*broadside-coupled microstrip-slot'*. Selepas penapis laluan jalur ini direka, penapis laluan jalur ini akan disimulasi menggunakan perisian alat simulasi elektromagnetik. Terdapat tiga reka bentuk yang direka dan keputusan yang diperoleh daripada simulasi akan dibandingkan dengan keputusan simulasi penapis laluan jalur yang lain. Kehilangan pulangan adalah kehilangan kuasa semasa isyarat melalui proses penghantaran manakala kehilangan pemasukan adalah kehilangan kuasa sebab berlakunya refleksi kuasa kembali kepada sumber kuasa. Penapis yang mempunyai kehilangan pulangan yang tinggi dan kehilangan pemasukan yang rendah akan dianggap sebagai penapis jalur lebar yang bagus kerana ia sensitive. Apabila penapis jalur lebar yang terbaik telah pun dipilih maka ia akan direka bentuk. Tesis ini membuktikan bahawa penapis *'Type 2'* memberikan hasil yang terbaik antara penapis *'Type 1'* dan *'Type 3'*. Data yang diperoleh daripada hasil simulasi menunjukkan bahawa *'Type 2'* mempunyai kehilangan pulangan yang tertinggi iaitu 25.32 dB dan kehilangan pemasukan terendah iaitu 0.15 dB.

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LIST OF SYMBOL

Symbol	Meaning
w	Width of strip conductor
t	Thickness of the transmission line
h	Height of the substrate
ε_r	Dielectric constant
ε_e	Dielectric constant of microstrip line
S_{11}	Scattering parameter
S_{21}	Scattering parameter
Zo	Characteristic impedance
l_{sir}	Length of stepped-impedance resonator
λ_e	Length of resonator
Zr	Ratio of the impedance of the two ends of the SIR to impedance of the middle section of the SIR.
π	Ratio of a circle’s circumference to its diameter

LIST OF ABBREVIATION

Abbreviation	Meaning
UHF	Ultra High Frequency
SHF	Super High Frequency
EHF	Extreme High Frequency
MUT	Material Under Test
CST	Computer Simulation Technology
ISM	Industrial, Scientific, and Medical
RF	Radio Frequency
ITU	International Telecommunication Union
SAR	Synthetic Aperture Radar
SIRs	Stepped-impedance Resonators
TEM	Transverse Electromagnetic
KG	Kilogram
MHz	Mega hertz
GHz	Giga hertz
WLAN	Wireless Local Area Network
CPW	Coplanar Waveguide

MMR	Multiple Mode Resonator
FBW	Fractional Bandwidth
CF	Coupling Factor
dB	Decibel
S-Parameter	Scattering Parameter
SMA	Sub-miniature A

CHAPTER 1

INTRODUCTION

1.1 Introduction

The applications of microwave sensors are wide. Generally, it is a device that keeps developing and more are being developed. The microwave sensors operate at frequencies range from 300 MHz to terahertz [1].

In order to understand the fundamental of microwave sensor, it is important to identify the word ‘microwave’. The short definition of microwave as stated by [2] is a short wavelength of electromagnetic wave. However, the nature of microwave and other electromagnetic waves are different. This statement is further elaborated by [2] that the size of the physical electronic component is roughly the size of the wavelength which the component act differently than the one in lower frequency. The microwave frequency spectrum is divided into three categories which are Ultra High Frequency (UHF) operates from 0.3 to 30 GHz, Super High Frequency (SHF) operates from 3 to 30 GHz, and Extreme High Frequency (EHF) operates from 30 to 300 GHz [3]. In [3], microwave described as tiny size of wavelength, broad bandwidth, propagate on the line-of-sight paths, transmission through ionosphere with slight absorption and reflection, cramped antenna size and reflection from metallic surfaces, microwave heating and microwave resonance in molecular atomic and nuclear systems. Due to this description, it has widened the application of microwaves in communication, radar, astronomy, basic and applied research, industry, and biomedical fields.

Consequently, sensors are widely used in industry because microwave sensors are effective in sensing and not sensitive to the environment. The capacity of a microwave range frequency is able to do the sensing task which is a great advantage [4]. It enabled the sensor and the Material Under Test (MUT) to communicate in a non-invasive, non-ionizing, and contact-less manner, which allows the information of the MUT can be extracted further as explained in [4]. Thus, the test subject information could be extracted without having to affect the quality and condition of the material.

Rice is known as Asian staple food across income classes, and Malaysia is not an exceptional. In [5] the author claimed that the Asian consume 100 kg per capita of rice annually, which proves that rice is their main source for carbohydrate. However, when there is a rise of income, people tends to change their diets, then will cause per capita rice consumption to decline. In [5] it is mentioned that, in the last four decades, the well-developed countries such as Japan, Taiwan and South Korea already shown a major decline in per capita, and Malaysia as a middle-income country demonstrate similar patterns in the last two decades, as people are more prone to eat more meat. Instead of seeing the variation of rice consumption trend across the world and see how income will affect the food habits, which is highlighted in [5] that the request for rice will continue to rise.

In Malaysia, the demand of rice is greater than the domestic production [6]. According to author in [6], Malaysia chose to retain as importer of rice because of its policy of emphasizing production in granary in 1984. In 1985, 1.26 million tonnes of rice was produced with the self-efficiency of 84% and 43% for Peninsular and East Malaysia respectively and with overall self-efficiency of Malaysia was 75%, which converted into a national per capita consumption of 108 kg. During the period of 1980 to 1985, the per capita consumption fluctuated and declined for over a longer period when the population increased which concludes rice is an inferior good and speculation been made that the declination of the per capita consumption was due to the changes in lifestyle and taste [6].

Meeting the rice demand is always related with the rice availability, quality control and the country’s economy. The basic thing to assess on picking the right physical characteristic are the size and shape of grain, colour, head rice recovery, and chalkiness [7]. Rice is categorized in two classes which are the Indica and Japonica [8]. Each of the classes is subdivided into two categories which are Basmati, Jasmine, Uruchi-mai, and Glutinous rice. Each of these classes of rice had its own quality and price.

Therefore, this research will be conducted to investigate wideband band pass filter parameters, and design wideband band pass filter using broadside-coupled microstrip-slot technique as a low cost microwave sensor for characterizing quality of rice. There will be three filter designs which are Type 1, Type 2, and Type 3. The insertion loss and return loss will be analysed and compared. The filter with the highest return loss and lowest insertion loss will considered as a good filter because it signifies the filter is sensitive. When the best filter is determined then the filter will be fabricated.

1.2 Problem Statement

There are many rice quality measurement devices available, however they are expensive. The quality of rice is determined by using these measuring instrument such as rice grain tester, automatic rice grader etc. The grain tester such as '*Sinar AP model 6060'* (refer to Figure 1.1) is highly regarded for its reliability and accuracy however the price is high [9]. Rice as a staple food for Asian community means there will be a lot of rice quality needs to be measured in order to categorized and sell them with its respective prices.

By comparing a microwave sensor with the '*Sinar AP model 6060*', microwave sensors are easier to fabricate and cost lower. Therefore, with microwave sensor as the solution to substitute the present rice quality measuring devices, the lower cost of measuring instrument can be presented.

Figure 1.1: Sinar AP model 6060 [10].

1.3 Objectives

The objectives of this research are as follows:

i. To investigate on the wideband band pass filter design and operation.
ii. To design wideband band pass filter using broadside-coupled microstrip-slot technique as a microwave sensor which can be used later in characterizing the quality of rice.

1.4 Scope of research

The scope of this research is to design wideband band pass filter operating at 2.45 GHz by using broadside-coupled microstrip-slot to be used as microwave resonator which can later be used in characterizing and measuring rice quality. The substrate material chosen is Rogers RO4003C. The designed filter is simulated and optimized using Computer Simulation Technology (CST) Microwave Studio. There will be three band pass filters to be designed and simulated. The obtained results from simulations will be analysed and determined which filter among the three gave the best performance.

1.5 Thesis Outline

The main purpose of this research is to design the microwave sensor by using band pass filter operating at 2.45 GHz for measuring rice quality. This thesis is divided into five chapters.

Chapter 1 introduces the project background and the problems statement. This chapter also includes the scope of the study and the objectives of the research.

While, Chapter 2 provides the literature review for the research which describes the information related to the microwave sensor studies, which include the type of microwave sensor, and the type of filter used.

Moreover, Chapter 3 discusses the methodology of how this study will be executed. Three important phases are elaborated in this chapter, which include the designing phase, simulation phase, and optimization phase.

Meanwhile, Chapter 4 shows the wideband band pass filter design and its simulated result. The results obtained from all three filters are compared.

Lastly, Chapter 5 wrap the whole project with some future recommendations for the thesis.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the Industrial, Scientific, and Medical (ISM) band are reviewed since there are varieties of band across the globe according to their standards. Also, microwave sensor and its application will be elaborated in this chapter. Lastly, the basic concept of the filters is also reviewed and summarized in this chapter.

2.2 Industrial, Scientific, and Medical Band

Devices that utilizes radio frequency is often relate to the term Industrial, Scientific and Medical (ISM) such as microwave, medical equipment, process heating and many more. The term ISM is define as the process of an equipment or appliances created to develop and use radio frequency energy industrial, scientific, medical, domestic, except applications in the field of telecommunications [11]. ISM band usage are prioritized for non-commercial use of RF electromagnetic fields for industrial, scientific and medical purposes however, each countries designated band may be vary due to the difference in national radio regulations [12]. The differences of ISM band according to region is depicted in Table 2.1.

For Malaysia, the designated ISM band is around 2.45 GHz which is using the spread spectrum modulation technique [13]. The 2.45 GHz band are popular because of it suitability for low-cost radio frequency such as wireless personal area network and wireless local area network (WLAN) [14]. The advantages and disadvantages of ISM bands are stated in Table 2.2.

Table 2.1: ISM band and its region [13, 14].

Band	Region
433 MHz	Region 1 (Europe).
828 MHz	Region 1 (Europe).
915 MHz	Region 3 (Australia/New Zealand) Region 2 (USA/Canada).
2.45 GHz	Region 1, 2, and 3. (Malaysia included)

Table 2.2: Advantages and disadvantages of different ISM band [14].

Band	Advantages	Disadvantages
433 MHz	1. Long range. 2. Good indoor signal penetration. 3. Slight path loss.	1. Congested in some frequencies. 2. Low quality and expensive system.
828 MHz	1. Medium range. 2. Less congestion	1. Complex
915 MHz	1. Wide range up to 1km. 2. Small antenna.	1. Less or limited application. 2. Need better adjustment for ISM usage. 3. High power consumption.
2.45 GHz	1. High data-rate. 2. Low cost and versatile.	1. Short range but can be increased using repeater. 2. High path loss.

There are three challenges that affects the efficiency of a device operate at ISM band which the first one are harmonization of ISM bands. As displayed in Table 1, ITU region 1, 2, and 3 has different range of ISM band. The different range of frequency are varies for global or local usage which requires harmonization [14]. Secondly, increasing spectrum demand. According to [14] the number of device operates in ISM bands are proportional to the number of spectral demand. Increasing the spectral demand however is narrowed due to limited existing spectrum but this problem could be solved by cognitive spectrum approach and operation in unauthorized spectrum which further explained in [14]. Thirdly, interference coordination. It is mentioned in [14] the probability of interference issue in usage of hardware and software from different vendor is necessary to identified and prevent by using band specification mitigation technique which allows harmonious operation between heterogeneous ISM devices.

2.3 Microwave Sensor

The term microwave sensor is derived from two separate words, sense and microwave. It can be defined as a device that detects short wavelength or electromagnetic wave. The presence of electromagnetic radiation in the microwave is detected to give required information [15]. This statement is supported by [16], where the unique information derived from the frequency characteristic can be obtained from microwave remote sensing of the microwave radiation which allows observation without any restriction. There are three classes of microwaves which are UHF, SHF, and EHF which can be observed in Table 2.3 [3].